Proceedings
of the International Symposium on
Cartographic Cutting-Edge
Technology for
Natural Hazard Management

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Produced by:
Dresden University of Technology
Institute for Cartography

Printed by:
Druckerei Wagner, Nossen

NB: Not all speakers submitted full-length versions of their papers. In these cases the abstracts are printed instead.

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Kartographische Bausteine, Band 30, 2005
ISBN: 3-86005-475-9
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Actor-oriented flood risk maps as support for societal decision making

Summary

This contribution describes and evaluates existing concepts of flood hazard- and flood risk maps with the focus on map functions and map types as well as their different contents and design methods. On the basis of this, it examines the particular requirements of the institutional and private actors regarding risk maps for regional flood risk management. Examples of flood hazard and flood risk maps will be given for the catchment area of the River Weisseritz near Dresden. This region was seriously affected by the extreme flood event in 2002. All maps are realized with a Geographical Information Systems (GIS). Results of interviews of main actors of the Weisseritz catchment area to the different concepts of flood risk maps and suggestions for the conception and design of user- and task-oriented maps are be presented. It is proposed to build up interactive information systems for the flood risk management like Web-GIS, map- and data services and to use new visualisation techniques to realize more actor-oriented maps.

1 Background

During the last years the paradigm changed of how to mitigate the impacts of disasters like extreme floods. It has been realised that an absolute protection from disaster is not possible and that a certain risk has to be tolerated. This opinion determines the planning of measures against disasters as well as the perception of dangers in the general public. In the field of flood protection the described change results in the development of flood risk management and assessment. In comparison to the conventional process of flood protection in the integrated process of a flood risk management more and different actors are involved. Because of this, more and especially actor-oriented information is required. In a case study in the catchment of the River Weisseritz, different concepts of flood hazard and flood risk maps were realized with Geographical Information Systems (GIS). Their applicability for local and regional actors was tested by interviews with main actors of the Weisseritz catchment area.

2 Integrated flood risk management

Flood risk management has recently been defined as „continuous and holistic societal analysis, assessment and mitigation of flood risk“ (SCHANZE 2005a,b). Both, the hazard and the vulnerability of the society are considered. Society, represented by politicians, experts and individuals, is the managing system due to manifold interrelations between society and floods (PARKER 2000). Main task of this management is the analysis of current flood risk, its assessment and the development of mitigation measures. The society requires information from flood risk analysis as basis for decision making. This assessment means weighing reachable benefits of utilization of source and flood-prone areas with potential damages and
costs for mitigation measures (Schanze 2004). It deals with the reduction of anthropogenic intensification factors of flood hazards in source areas and pathways and the reduction of vulnerability in receptor areas. Risk mitigation can be distinguished in pre-flood, flood event and post-flood measures (Samuelse 1999). Due to the flooding process decision making for flood risk management has to refer to river basins. But these hydrological defined areas are not spatially congruent with administrative boundaries of municipalities. Therefore, approaches for the collaboration of municipal actors and other stakeholders (e.g. water authorities, spatial planning authorities) within river basins have to be developed.

Risk maps are a tool for presenting the results of the flood risk analysis also on the scale of whole catchments. They show the endangered areas with their various risks and therefore are a prerequisite for a site-specific risk assessment. Based on model-based simulations of future risks they can also display the effects of alternative mitigation measures and instruments. Accordingly, risk maps are one of the main tools of decision-support. They provide information on the spatial distribution of risks with their qualitative and quantitative parameters. Due to a wide range of possible parameters and users this information can be presented quite differently.

3 Basic principles of actor-oriented Cartography

Modern interactive information systems, especially on the internet, allow creating different maps for the specific requirements of actors of flood risk management with their varying knowledge and tasks. Thus, the technical basis to realize actor-oriented maps exists. But we are still lack of knowledge how to design these maps that they really support the different actors and their tasks.

Cartography developed several methods for map design which are based on aspects of communication, perception and map function. For an actor-oriented map design, however, it is necessary to incorporate and accentuate the the map user’s task and related activities. Thus, an actor-oriented cartography has to take a closer look to activities and to develop principles for an actor-oriented map design. Activity theory gives a good framework for this (Dransch 2003).

According to that theory an activity can be described as a process in which actions are planned, executed and evaluated. Human activities are always initiated by and directed to a specific goal. The goal determines and structures each activity. Activities are inextricably linked with a certain situational context. The context shapes the action goals, it defines the community of persons who are involved in an activity and their roles, finally it determines the rules and circumstances that effect an activity. Activities are performed with the help of artefacts. For that reason, artefacts have a particular significance: They are mediators between the intended goal and the activity’s result. The artefacts’ properties and characteristics decisively influence the way in which an activity can be performed and also the quality. They also determine if the goal can be fulfilled at all. Artefact and action stand in a strong relationship to each other. The artefact’s properties determine the action; the action, conversely, defines the artefact’s properties. Activities also influence a person’s knowledge and vice versa. Thus, an actor’s knowledge is closely related to his activities (Nardi 1996).

According to this concept maps are regarded as artefacts that are used to execute activities. Consequently, map design has to consider all aspects related to activities as mentioned above (Dransch 2001). In the field of risk maps following issues on actor-oriented map design should be taken into account:

- What are the different goals in risk management process and what activities have to be accomplished to reach these goals? Which scenarios are possible? How can maps support the activities and goals?
- Who are the actors in the complete risk management process and what are their roles?
Which actors have to cooperate and communicate with each other? How can this cooperative work be assisted by maps?

- How can the map-use situation be characterized? Is it time critical, dynamic, busy? Are there any rules that have to be considered?

In our research work we made a first step to investigate actor-oriented maps. We examined various existing flood hazard and flood risk maps and asked different actors if they are suitable artefacts for their specific tasks and how the maps should be changed to become a more useful artefact for their work and decision making.

4 The initiative „Weisseritz-Regio“

This work on risk maps is part of the research project „Co-operative flood risk management using an environmental information system – the River Weisseritz catchment (Weisseritz-Regio) (S.a. http://www.ioer.de/weisseritz) of the Leibniz Institute of Ecological and Regional Development (IOER), Dresden. As a transdisciplinary pilot scheme it has innovation potential and strong application relation as well.

The Weisseritz river is a left tributary of the river Elbe in Saxony with a catchment size of 386 sqkm. In August 2002 the Weisseritz inundated large urban areas and the countryside along the river. The city centres of Dresden and Freital were heavily affected by this flood event (LrUG 2004). The relief and the geomorphology of the catchment area cause high precipitations in the upper part of the catchment and a high surface run-off. As a consequence the type of of the flood events can be characterized as “flash floods”.

The aim of the Weisseritz project is to develop and test a theoretically and methodologically framework of regional informal co-operation in terms of flood risk management in river catchments, especially such concerned by flash floods. The co-operation should be based on the collaboration of all actors either concerned by floods or able to contribute to flood prevention (HUTTER 2004).

Therefore, first of all the co-operation process between municipalities, state authorities and land users in the Weisseritz river catchments was initiated and goal-oriented structured. The most important stakeholders in the case of flood prevention were identified. 25 institutions agreed to work together:

- the Weisseritz County (Landkreis)
- 14 local authorities, including the City of Dresden
- the Regional Planning Office
- 5 institutions of the Free State of Saxony
- 3 non-governmental organisations and
- one scientific institute.

The co-operation of these institutions is based on a common declaration. In the paper the members express there willingness to collaborate voluntarily towards the improvement of flood prevention in the Weisseritz area. As the nature of the co-operation is informal only a few rules are stipulated. So the members declared to provide the needed information and to nominate staff in the co-operation bodies (WIRTH & SCHANZE 2004).
5 Concepts of flood hazard and flood risk mapping

5.1 State of the art of flood hazard- and flood risk mapping

Different concepts of flood hazard and flood risk maps do exist already in Europe. They vary regarding to design, map content respectively considered data, aggregation of data and fields of application. The maps visualise flood hazards (e.g. inundation areas with different flood probabilities, flood depth, flow velocity, flood duration, waterside erosion, mudflow sediment) and flood risks (e.g. expected annual damages to properties).

The use and the legal basis of hazard and risk maps are very different in the various countries. In Switzerland for example, different types of flood risk maps are prescribed by regulations, their use for spatial planning is obligatory (LOAT et al. 1997). In Germany concepts of flood risk maps exist, too, but they were not legally prescribed nationwide. As a reaction to the flood event in 2002 in the Free State of Saxony the Water Act was reformulated in 2004. Now the preparation of hazard maps is obligatory (SMUL 2004).

The following chapter 5.2 gives some examples of existing concepts of flood hazard and flood risk maps in Europe. The given examples are compared in chapter 5.3. For each concept an example map for the test site “Schmiedeberg” in the Weisseritz catchment was created in accordance to the existing concepts and cartographic design on a scale of 1:5000 (ETTER 2005: 76ff). For this purpose we used the tools and methods of Geographical Information Systems (GIS).

5.2 Examples of existing concepts

Hazard Map (Switzerland)

The hazard map developed in Switzerland determines areas („hazard zones“), which are expelled for certain use due to the flood hazard. The hazard zones are aggregated on the basis of the flood probability and the potential flood intensity by means of the so called intensity-probability-diagram (figure 1). The potential flood intensity depends on the flood depth, the flow velocity, the bank erosion and the mudflow sediment. The classification of the potential flood intensity (strong, average and weak) follows possible effects on areas of settlement (EGLI 1996: 53ff; LOAT et al. 1997: 16ff).

The particular hazard zone (low, average or considerable) determines the application of different guidelines for spatial planning. The guidelines were primarily aligned with consequences of flood events on landuse types. They were set up to support the mitigation of possible effects of flood hazards to human beings and animals as well as to material assets. In the hazard zone of considerable hazard for example, no further buildings or constructions are allowed (LOAT et al. 1997: 25ff).
The concept of the hazard map from Switzerland was adapted by the official water management authority (Landestalsperrenverwaltung Sachsen). For two test sites in the catchment areas of the Müglitz and the Weisseritz (Schlottwitz and Schmiedeberg) the concept was evaluated for its feasibility (LFUG 2004).

Risk and Protection Deficit Map (Switzerland)

The risk and protection deficit map offers information about the potential risks to property and about areas with protection deficits. It bases on the hazard maps described before. A protection deficit exists, if the intensity of the flood of a specific probability exceeds a defined threshold value ("protection aim") (table 1). The category of the particular object (e.g. industrial zone) specifies the applicable threshold value. The potential risk of a property is expressed as the expected annual damage to the property (EGLI 2001: 83f). The Risk- and Protection Deficit Map is used as basis of cost-effectiveness analysis of protection measures. The protection deficits illustrate under-protected areas and regions of high risks (EGLI 2001: 84). Figure 2 shows the application of the concept of the Risk and Protection Deficit Map for the test site “Schmiedeberg”.

<table>
<thead>
<tr>
<th>Category of objects (examples)</th>
<th>Protection aim [max. allowed intensity]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr. Material assets</td>
<td>Infrastructure objects</td>
</tr>
<tr>
<td>1</td>
<td>Trails</td>
</tr>
<tr>
<td>2.1</td>
<td>Uninhabited buildings</td>
</tr>
<tr>
<td>2.2</td>
<td>Temporal or constant inhabited single buildings and hamlets</td>
</tr>
<tr>
<td>3.1</td>
<td>Settlements, Commercials and industrial sites, camping sites,</td>
</tr>
<tr>
<td>3.2</td>
<td>Special risks</td>
</tr>
<tr>
<td>3.3</td>
<td>Special risks</td>
</tr>
</tbody>
</table>

0: intensity zero
1: low intensity no endangerment of people outside of buildings; low degree of damage to material assets
2: middle intensity no endangerment of people inside of buildings, but outside; middle to high degree of damage to material assets
3: strong intensity endangerment of people outside and inside of buildings; high degree of damage to material assets

Table 1: Matrix of protection aims, adapted from EGLI (2001: 86).
Risk Map of Insurance Companies (Germany)

German insurance companies (Gesamtverband der Deutschen Versicherungswirtschaft e. V. (GDV)) developed the „Zone System for Localisation of Hazard Areas in Case of Flood, Retention and Heavy Rain (ZÜRS)“. It allows the cartographic visualisation of so called „zones“ in risk maps of insurance companies. The zones are derivated from the probability of floods and the consequent flood plains (table 2). The maps serve insurance companies as basis for decisions about the insurability of objects (MÜLLER 2001; FALKENHAGEN 2004; GDV 2004).

<table>
<thead>
<tr>
<th>Zone</th>
<th>Hazard</th>
<th>Probability of floods</th>
<th>Insurability</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>very low</td>
<td>Floods no more than every 200 years</td>
<td>Full possibility</td>
</tr>
<tr>
<td>II</td>
<td>Low</td>
<td>Floods every 50 to 200 years</td>
<td>In principle possible</td>
</tr>
<tr>
<td>III</td>
<td>moderate</td>
<td>Floods every 10 to 50 years</td>
<td>In most instances not possible</td>
</tr>
<tr>
<td>IV</td>
<td>High</td>
<td>Floods at least every 10 years</td>
<td>In general not possible</td>
</tr>
</tbody>
</table>

*Table 2: Zoning of flood hazards in risk maps of insurance companies, GDV (2004).*
Risk of Damage Map (Germany)

The risk of damage map visualises the spatial distribution of potential risks of damages. The potential risk of a damage is expressed as the expected annual damage to a property. It is divided into different risk zones. The potential risk of damage is apprehended as the interaction of flood hazard and vulnerability. The vulnerability is calculated by application of damage functions (e.g. HOWAS data base of the Bavarian water resources authority), which determine the damage of a single object depending on the flood depth. The Risk of damage map supports the economic assessment of flood prevention measures within the scope of cost-benefit analysis. In addition, it can be used as basis of the calculation of insurance premiums (MERZ & GOCHT 2003). The result of the example map for the test site “Schmiedeberg” shows figure 3.

Figure 3: Risk of damage map of the test site „Schmiedeberg“ in the Weisseritz catchment. Cartographic presentation (colors etc.) in accordance with the original concept of MERZ & GOCHT 2003. (Processing: J. Etter; Data Source: Topographic map 1:10.000, Land survey office Saxony, License-No. 173/05).

Rhine Atlas (Switzerland, Germany, France, Netherlands)


Rhine Atlas – Hazard Map
The “Rhine Atlas – Hazard Map” visualises the inundation areas of a 10 year and a 100 year recurrence as well as the flood plain and the flood depth of an extreme flood event in classes (<0.5 m, 0.5 - 2 m, 2 – 4 m, >4 m). The classification of the flood depth follows the expected effects of static flood events on persons and material assets (e.g. the danger to loss of life and a high probability of total destruction of material assets exists in the case of a flood depth with more than 4 m). Additionally, the Rhine Atlas – Hazard Map gives information about the affected (0 m > flood depth < 2 m) and endangered (flood depth > 2 m) persons in case of an extreme flood event (IKSR 2001: 3ff).

Rhine Atlas – Map of Potential Damages to Property
The „Rhine Atlas – Map of Potential Damages to Property“ provides information about possible damages of an extreme flood event. On the basis of specific property assets and flood depths of an extreme flood event, potential damages are calculated by means of the application of damage functions (HOWAS; see above). The possible damages are differentiated on the land use (areas of settlement, areas of industry, traffic areas, areas of agricultural use) (IKSR 2001: 5ff). Figure 4 shows the result of the application of this concept for the test site “Schmiedeberg”.

Figure 4: Map of possible damages (Concept of the Rhine atlas) of the test site „Schmiedeberg“ in the Weisseritz catchment. Cartographic presentation (colors etc.) in accordance with the original concept. (Processing: J. Etter; Data Source: Topographic map 1:10.000, Land survey office Saxony, License-No. 173/05).
5.3 Comparison of concepts

The comparison of the delineated concepts on the basis of table 1 leads to the following results (ETTER 2005: 49ff):

**Map contents:**
- All concepts consider inundation areas of different flood probabilities. The considered flood probabilities are heterogenous.
- The flood depth is explicitly visualised just in the concept of the “Rhine Atlas - Hazard Map”. No concept considers earlier events.

**Visualisation of hazard and/ or risk:**
- Only the “Risk of Damage Map” and the “Risk- and Protection Deficit Map” combine hazard and vulnerability to a risk by means of the consideration of different scenarios. The “Rhine Atlas - Map of Possible Damages” also determines a certain risk by means of considering just the extreme flood event.
- No concept considers the ecological vulnerability and indirect effects.

**Field of application:**
- The concepts are primarily developed for water authorities, spatial planning and insurance companies.
- Only the Rhine Atlas maps adress all users, also the potential affected and endangered citizens.
- No concept is explicitly developed for the use in a flood risk management process.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Map contents</th>
<th>Visualisation of hazard and/ or risk</th>
<th>Fields of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard Map</td>
<td><em>Hazard zones</em> aggregated on basis of flood probability, flood depth, flow velocity, waterside erosion and mudflow sediment</td>
<td>Hazard</td>
<td>Spatial planning</td>
</tr>
<tr>
<td>Risk Map of Insurance Companies (ZÜRS)</td>
<td><em>Floodplain of HQ</em>_{10/50/200/200}</td>
<td>Hazard</td>
<td>Verification of insurability of objects</td>
</tr>
<tr>
<td>Risk and Protection Deficit Map</td>
<td><em>Protection deficits</em> determined on basis of hazard zones (hazard map), category of objects and protection aims Expected annual damage to property aggregated on basis of the intersection of flood plains, different flood probabilities and land use plan</td>
<td>Hazard</td>
<td>Cost effectiveness analysis of protection measures Determination of regions with protection deficits</td>
</tr>
<tr>
<td>Risk of Damage Map</td>
<td><em>Expected annual damage to property</em> aggregated on basis of the intersection of flood areas, different flood probabilities and land use plan by means of damage functions</td>
<td>Risk</td>
<td>Cost-benefit analysis of protection measures Determination of insurance premiums</td>
</tr>
</tbody>
</table>
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Table 3: Comparison of hazard and risk map concepts in Europe (Compilation: Etter).

<table>
<thead>
<tr>
<th>Rhine Atlas – Hazard Map</th>
<th>Rhine Atlas – Map of Possible Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floodplain of $H_Q_{10/100/entreme}$</td>
<td>Possible damages in the case of an extreme flood event</td>
</tr>
<tr>
<td>Flood depth of $H_{Q_{entreme}}$</td>
<td>determined on the basis of flood depth and specific property assets by means of damage functions</td>
</tr>
<tr>
<td>Affected and endangered persons in the case of an extreme flood event</td>
<td>Hazard</td>
</tr>
<tr>
<td>Basis for flood protection measures (Action plan Rhine) Reinforcement of flood awareness of the public</td>
<td>Risk</td>
</tr>
<tr>
<td>Basis for flood protection measures (Action plan Rhine) Reinforcement of flood awareness of the public</td>
<td></td>
</tr>
</tbody>
</table>

5.4 Interviews to the concepts

Objectives

The main objective of the interviews was to get information about the applicability of the delineated concepts for decision support in flood risk management process. Further questions arose from the main objective (ETTER 2005: 86):

- Which experiences already exist in the use of flood hazard and flood risk maps?
- Which decisions of flood prevention of the interviewed actors can be supported by such maps?
- Which map content would be necessary for the different decisions and activities?
- How do the interviewed actors evaluate a publication of flood hazard and flood risk maps?
- Which other professional experience and knowledge of the interviewed actors are significant regarding the usability of flood hazard and flood risk maps for flood risk management of the Weisseritz?

Realisation

For the interviews the different created flood hazard- and flood risk maps of Schmiedeberg (a certain region within the Weisseritz river catchment) were used as basis for the discussion. The interviews were realised as expert interviews with main actors of flood risk management in the Weisseritz river catchment. The following main actors were involved (ETTER 2005: 86ff):

- Municipalities
- Water Management Authorities
- Advocacy group
- Environment department
- Forest department
- Regional planning authority
- Building authority

Results

First of all, the interviews showed that the experience and knowledge about flood hazard and flood risk maps are limited. Little experience in their application is given, no actor used such maps for decision
support so far (Etter 2005: 89).

As a second result the interviews made clear that decisions and tasks the interviewed actors have to fulfill are heterogeneous; and that a map’s usability depends on the different actors and tasks. Generally, useful map content are inundation areas and flood depths of different scenarios as well as flow velocities. The specific geographic characteristics of the Weisseritz river catchment (Chapter 4) that brings forward dynamic flood events of short forecast lead time (in particular flash floods) additionally requires the explicit consideration of the flow velocity (Etter 2005: 89ff). Depending on the individual tasks and decisions that have to be supported, different scales are necessary. The interviewed actors gave also lots of suggestions for differentiation and completion of the existing concepts and maps: e.g. the visualisation of hot spots, which are characterised as particular endangered areas, or the consideration of historic flood events as well as the presentation of retention capacity were proposed. A 3D-visualisation of flood hazards could be an appropriate form of a clear depiction of a flood event and its possible effects (Etter 2005: 91ff).

A publication of flood risk maps is approved generally. The reinforcement of flood awareness, the development of a personal responsibility and the general mediation of information could be positive effects of a publication. Problems with protection of data privacy and with the quasi-accuracy have to be considered. Therefore, an appropriate presentation in terms of explanations, simple verbalisation or clear graphical presentations of information is necessary (Etter 2005: 92f).

6 Conclusions

Integrated flood risk management has to be based on societal decision making which integrates different actors and interests. Information is necessary that support this decision making process in a suitable way. Hazard and risk maps which combine hazard and vulnerability are excellent means for this. However, it is important to design the risk maps corresponding to the different actors’ need. The various actors have individual tasks and knowledge and, therefore, they require various actor-oriented map concepts and visualisation methods. In a case study in the Weisseritz river catchment we investigated some existing concepts of flood hazard and flood risk maps and tested their usability. The results show strengths but also shortcomings of the maps. Suggestions of actors in the case study give an idea of how to improve existing hazard and risk maps for specific requirements. On the technical side, actor-oriented maps require technology that allows fast and user driven map creation, as well as an easy access to the information. Interactive information systems, new visualisation techniques as well as the internet with Web-GIS, Web-Mapping and data services are suitable technologies and should be used to realize more actor-oriented maps.

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